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Adaptive Relay Selection Scheme by Using Compound Channel

Yu-Jin Na [1], Won-Seok Lee [1], Min-Jae Paek [1], Hyoung-Kyu Song [1,*], Duckdong Hwang [1] and Young-Hwan You [2]

1 Department of Information and Communication Engineering, Sejong University, Seoul 05006, Korea; yuna4306@daum.net (Y.-J.N.); scu008@nate.com (W.-S.L.); uaty7861@naver.com (M.-J.P.); duckdonh@gmail.com (D.H.)

2 Department of Computer Engineering, Sejong University, Seoul 05006, Korea; yhyou@sejong.ac.kr

* Correspondence: songhk@sejong.ac.kr

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Abstract: As a cellular network of the fifth generation (5G) is commercialized, mobile devices and data throughput have rapidly increased. According to the spatial density for communication increases, the nodes of cell are overloaded. Therefore, the heterogeneous ultra dense network (UDN) is suggested. Furthermore, the techniques for selecting a relay have been proposed in the Heterogeneous Net (HetNet). The relays are needed to improve communication performance and mitigate overload of nodes. In this paper, an adaptive relay selection scheme is proposed to obtain the diversity gain from multiple relays. To enhance the reliability of communication, the proposed scheme suggests a new algorithm considering outage probability and diversity gain of compound channel. Furthermore, the selected relays use an antenna selection algorithm to improve the channel capacity. Simulation results show that the proposed scheme improves the bit error rate (BER) and the data throughput.

Keywords: relay selection; cooperative systems; MIMO; outage probability; compound channel; antenna selection

1. Introduction

With the increase in the use of multimedia services such as mobile video and audio, traffic for communication is generated. In particular, micro cells with wide coverage could not guarantee stable long-term evolution (LTE) service in traffic-intensive urban areas or buildings [1,2]. As spatial density and mobile devices increase, the nodes of cell are overloaded [3]. In 5G, the heterogeneous UDN is proposed for both high data rate and a lot of data transmission with limited resources. The heterogeneous UDN is HetNet with an UDN structure that concentrates more small cells such as pico and femtocells than the HetNet used in the fourth generation [4]. The heterogeneous UDN improves spectral efficiency by increasing the network capacity per unit area of the cell [5]. It also distributes mobile traffic and satisfies 5G performance requirements such as user quality of service (QoS), quality of experience (QoE), lower latency and power consumption [6,7]. Data rate and reliability are significant elements of communication, but it is difficult to achieve high performance in a wireless system. Especially, if the network condition is poor, communication performance is degraded.

One-way or two-way relays are used to overcome poor network condition in cooperative communication systems. For same data rate, two-way relaying protocol improves transmission power consumption and spectral than one-way relaying protocol [8]. For this reason, two way relaying protocols have been studied actively to improve performance [9,10]. The relay can be used to decentralize the overload of cell nodes in a heterogeneous UDN system [11]. In addition to improvement of reliability for communication, relays can also offer a variety of benefits such as diversity gains, robustness for noise and expanded coverage ranges [12]. When the outage in the system occurs, these benefits cannot be acquired. In other words, if the channel capacity is less than the amount of data to transmit, a network system fails. So, accurate channel state information (CSI) is important to select a relay for the stability of the network system. In the communication systems, channel state information (CSI) is required to achieve the expected benefits. The CSI is mostly classified as full CSI and partial CSI. The researches of partial CSI [13,14] are progressed to compensate for the weakness of full CSI, which requires a lot of feedback. However, researches using full CSI [15,16] have been studied. In particular, as the relay node forwards the received signal, the stability between the source and the relay node is very important. Therefore, the relay with a largest channel capacity between the source node and the relay node should be selected using CSI. Researches have been studied steadily to reduce the outage probability in a cellular network using relays [17–20]. In the studies of the multi-hop system among these researches, it is essential to assume that the base station (BS) node and relay station (RS) nodes are connected with backhaul [21–23]. Although researches about wireless backhaul are in progress, but issues such as cost, flexibility, and wired and wireless convergence still remain unsolved. Furthermore, due to the difficulty of backhaul connections and the interaction between relays, researches on single hop have been studied actively to improve the performance of single link as an alternative of complex multi-hop systems [24,25]. These researches only consider system using a single relay. In relaying system, one of the primary issues is how to maximize the diversity gain [26–28]. The use of multiple relays is one way to maximize diversity gain, and various selection schemes for multiple relays have been studied on a single link [27,29,30]. Researches to reduce the outage probability of cellular network systems that generally use relays select a single relay with the lowest outage probability. Furthermore, the technique for relay selection according to the case of outage does not exist. However, the wireless network that is suitable for communication cannot always maintain the same channel condition, so outage occurrence is inevitable. Therefore, a new criterion is needed to select relays for different condition of the network.

This paper proposes an adaptive relay selection scheme to obtain the diversity gain through the optimal compound channel. To enhance the entire performance of system, the proposed scheme suggests a new algorithm consisting of two selection stages. Specifically, each stage of a new algorithm considers the outage probability at relays and diversity gain of compound channel. Furthermore, the selected relays use an antenna selection algorithm to improve the channel capacity of different users.

This paper is organized as follows. Section 2 presents the system model, Section 3 introduces the conventional schemes. Section 4 describes the algorithm and advantage of the proposed scheme. Simulation results are shown in Section 5. Finally, Section 6 describes the concluding contents.

2. System Model

Figure 1 shows two-hop MIMO relay system model in a wireless network. The system consists of one source node (S) node and each destination node D_u $(u = 1, \ldots, U)$. The number of antennas on S and D_u is the same as N_l. Furthermore, multiple relays exist in the system model. Each relay node is expressed as R_k $(k = 1, \ldots, K)$. R_k has N_r receiving antennas and N_t transmitting antennas. A set of R_k uses the decode and forward (DF) protocol. Since DF protocol demodulates received signal and re-encodes the signal before retransmission of the signal, effect of noise can be reduced. Direct links ($S \rightarrow D_u$) are assumed to be too weak support high quality transmission [31]. Therefore, direct links ($S \rightarrow D_u$) are not considered. Non-direct links ($S \rightarrow R_k$) and ($R_s \rightarrow D_u$) are only available. In addition, it is assumed that each node operating as a transmitter knows CSI through feedback according to transmission of a pilot signal to the receiver node. System model uses two time slots for signal transmission. S transmits signal to R_k during the first time slot. The received signal at R_k is as follows,

$$y_k = \mathbf{H}_k \mathbf{x} + \mathbf{n_r}, \tag{1}$$

where $\mathbf{x} \in \mathbb{C}^{N_l}$ is the transmitted signal vector from S. $\mathbf{H}_k$ is the $N_r \times N_l$ channel between S and R_k. Furthermore, $\mathbf{H}_k$ is modeled as Rayleigh fading. $\mathbf{x}$ is a signal transmitted from S. And $\mathbf{n_r} \in \mathbb{C}^{N_r}$ is an additive white Gaussian noise (AWGN) vector with zero mean and variance N_0 at R_k.

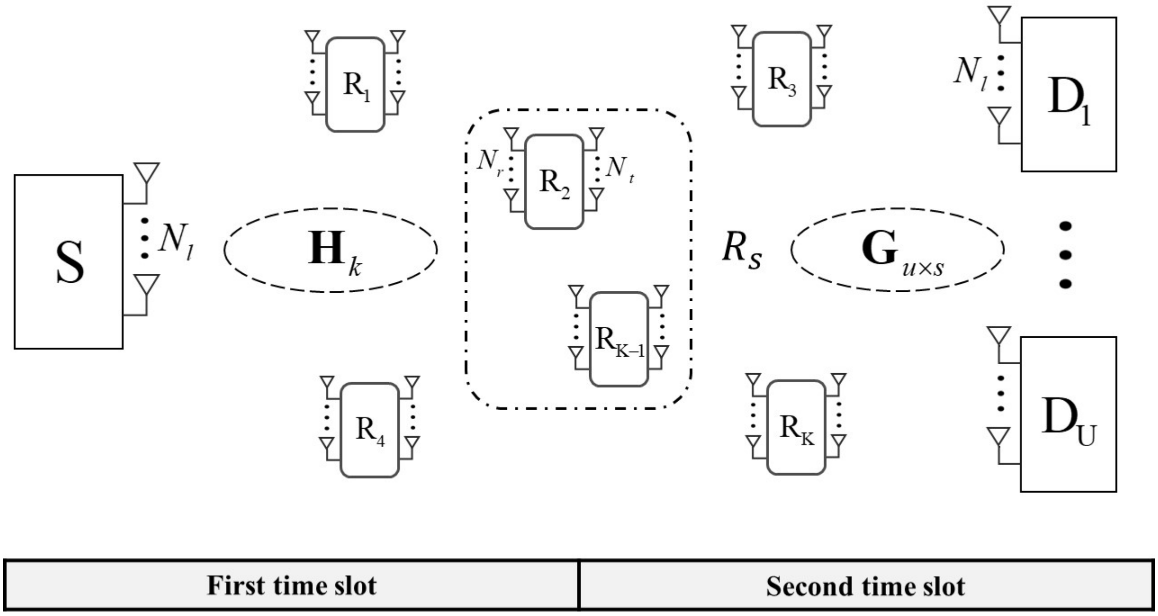

Figure 1. Two-hop MIMO relaying system.

During the second time slots, R_s transmits a signal to D_u. R_s $(s = 1, \ldots, S)$ is selected as a relay among a set of R_k. The received signals at D_u are as follows,

$$\mathbf{y}_u = \mathbf{G}_u^s \hat{\mathbf{x}}^s + \mathbf{n}_d, \tag{2}$$

where transmitted signal from a set of R_s is $\mathbf{y}_u = [\mathbf{y}_1, \ldots, \mathbf{y}_U]^T$. $\mathbf{G}_u^s$ is the $N_l \times N_t$ compound channel between D_u and a set of R_s. A compound channel is a combination of channels between relays that can be used to transmit to the same destination. Furthermore, $\mathbf{G}_u^s = [\mathbf{g}_u^1, \ldots, \mathbf{g}_u^S]^T$ and each $\mathbf{G}_u^s$ is modeled as Rayleigh fading. $\hat{\mathbf{x}}^s = [\hat{\mathbf{x}}^\mathbf{1}, \ldots, \hat{\mathbf{x}}^S]$ is retransmitted signal from R_s. N_l of D_u receives different signals. $\mathbf{n}_d \in \mathbb{C}^{N_l}$ is an AWGN vector.

3. The Conventional Relay Selection Schemes

In this section, the conventional schemes for selection of relay are considered. The various relay selection schemes have been proposed to enhance signal to signal-to-noise ratio (SNR) of receiving signal for different system environments [32–34]. The various schemes have a different criteria. In [35–37], relay selections are proposed to enhance energy efficiency so power consumption is the most important factor for the relay selection. The performance of the system always depends on the channel condition of the relay. The relay selection scheme is considered according to channel of the relay. Therefore, the most used criterion is the channel magnitude based on CSI from R. The relay selection schemes are explained as follows.

3.1. The Frobenius Norm-Based Selection Scheme

The Frobenius norm is defined as L_2-norm of the Euclidean norm. In Euclidean space, the Frobenius norm is the distance from origin. The Frobenius norm can be expressed as follows,

$$\|\cdot\|_k^2 = \sum_{i=1}^{N_r}\sum_{j=1}^{N_l}\left|a_{ij}\right|^2 = tr(\mathbf{H}_k^T\mathbf{H}_k) = \sum_{i=1}^{N_l}\sigma_i^2, \tag{3}$$

where $\|\cdot\|_k^2$ means square of the Frobenius norm of the k-th relay. a_{ij} denotes each channel element of $\mathbf{H}_k$ and $\left|a_{ij}\right|$ denotes the absolute value of a_{ij}. The Frobenius norm of relay equals the square root of a sum of all $\left|a_{ij}\right|^2$. And the diagonal entry in $\mathbf{H}_k^T\mathbf{H}$ is the sum of the squares of each column of $\mathbf{H}_k$. Therefore, the sum of the diagonal entries of $\mathbf{H}_k^T\mathbf{H}$ equals the total sum of $\left|a_{ij}\right|^2$. Furthermore, it is same with the sum of an eigenvalue $\mathbf{H}_k^T\mathbf{H}$. σ_i^2 means the square of singular value of $\mathbf{H}_k$. (4) presents the singular value decomposition (SVD) of $\mathbf{H}_k$. $\mathbf{H}_k$ can be described as follows,

$$\mathbf{H}_k = \mathbf{U}\mathbf{\Sigma}\mathbf{V}^H, \tag{4}$$

where $\mathbf{U}$ and $\mathbf{V}$ are unitary matrix. $\mathbf{\Sigma}$ is a diagonal matrix with singular value. σ_i is a component of $\mathbf{\Sigma}$.

The sum of an eigenvalue $\mathbf{H}_k^T\mathbf{H}$ is same sum of σ_i^2. In other words, the Frobenius norm depends on singular value. The Frobenius norm-based selection scheme calculates (3) for each candidate relays channel and selects the relay with the largest Frobenius norm.

3.2. The MIMO Capacity-Based Selection Scheme

Among the relay selection schemes, the scheme using MIMO relay channel capacity is frequently used [38–40]. The MIMO channel capacity of the k-th relay is as follows,

$$C_k = \log_2(\det(\mathbf{I} + \frac{\rho}{N_l}\mathbf{H}_k\mathbf{H}_k^H)), \tag{5}$$

where $\mathbf{I}$ denotes the identity matrix. ρ denotes average SNR at each antenna of the relay as $\frac{P_t}{N_0}$. P_t is transmitting power of the signal and N_0 is noise power. $\mathbf{H}_k^H$ means the Hermitian conjugate transpose matrix of $\mathbf{H}_k$.

According to (3)–(5) can be approximated as follows,

$$C_k = \sum_{i=1}^{N_l}\log_2(1+\sigma_i^2\rho). \tag{6}$$

As a σ_i^2 increases, available channel capacity also increases. The MIMO capacity-based selection scheme selects relay with the largest capacity using (5) or (6).

4. The Proposed Scheme

The proposed scheme uses a new algorithm to improve the performance of a single link. This new algorithm consists of two selection stages. In the first selection stage, the candidates for relay selection are determined according to the outage. After the determination of candidates, best relays and antennas are selected in the second stage. The following subsections explain the selection of the two stages. Figure 2 shows the flow chart of the proposed scheme.

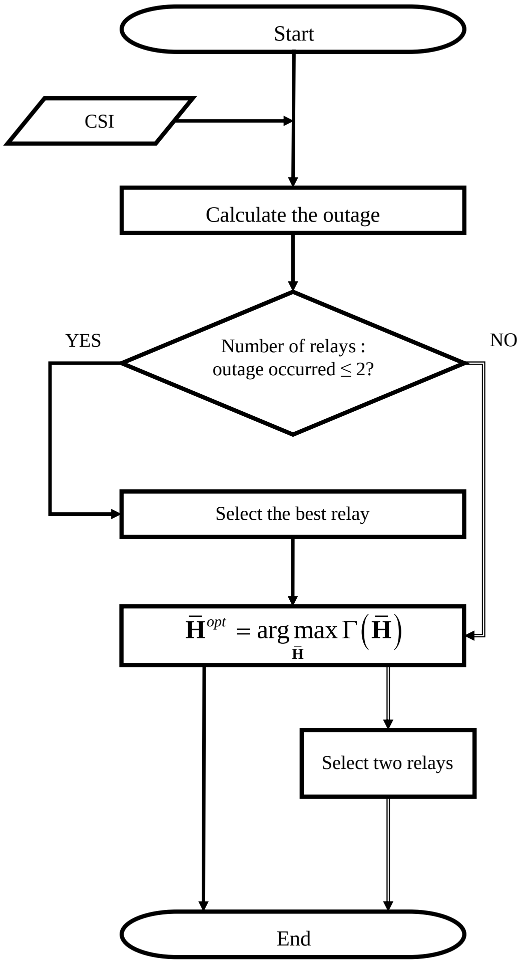

Figure 2. Flow chart of the proposed scheme.

4.1. Relay Selection with Outage

S receives feedback for the CSI before calculating the outage probability. Then, S calculates the outage probability of $\mathbf{H_k}$. The outage probability is calculated as follows,

$$O_k = \Pr[C_{\mathbf{H}_k} < B_{\mathbf{x}}], \tag{7}$$

where $C_{\mathbf{H}_k}$ is channel capacity of $\mathbf{H_k}$. $B_{\mathbf{x}}$ denotes the total number of bits in $\mathbf{x}$. If the transmitted data exceeds the channel capacity, outage occurs. If $C_{\mathbf{H}_k}$ is greater than $B_{\mathbf{x}}$, outage is not occurred. Relay satisfying (6) is defined as R_q. In other words, R_q is a set of qualified relays with non-outage.

When N_p is the number of relays using on the system, N_p is compared with the number of R_q. In this paper explain that the case where N_p is 2. The proposed scheme classifies three cases according to Q. Q is the number of R_q and R_q is a relay that outage does not occur among K relays. The relay is selected differently in each case. The case 1 considers $Q < 2$. If the $Q = 0$, throughput of all links through relays cannot be guaranteed due to the outage and $Q = 1$, only one relay can guarantee the reliability of data. Therefore, regardless of multiple relays, the relay that link between S and R_k has the best quality is selected. The number of the combination for case 1 is one.

If Q is two, the case is defined as case 2. In case 2, all R_q are selected. Therefore, the number of the combination for case 2 is two.

When the value of Q is greater than 2, the case is defined as case 3. Unlike case 1 and 2, the number of the combination for case 3 is not fixed. The combination number, N_c, is as follows,

$$N_c = \frac{Q!}{(Q-2)!Q!}. \tag{8}$$

Furthermore, the set of channel matrices between R_q and D_u is defined as follows,

$$\mathbb{Q} = \{\mathbf{H}_q | C_{\mathbf{H}_q} < B_{\mathbf{x}}\}. \tag{9}$$

4.2. Antenna Selection with Compound Channel

After the cases are identified, relay and antenna selection are performed by considering compound channel. In this selection stage, Frobenius norms of the compound channel are compared to find a best compound channel with antenna selection. In case 1, since only one relay is used, compound channel is not considered. The selected relay of case 1 performs only antenna selection. If the relay uses N_m antennas among N_t antennas, the set of channel matrices after antenna combination is as follows,

$$\bar{\mathbb{Q}}_q = \left\{ \bar{\mathbf{H}}_{q,t},\ t = 1, 2, \cdots, T_1 | N_m \,\text{columns are selected from}\, \mathbf{H}_q, \right\}, \tag{10}$$

where $\bar{\mathbf{H}}_{q,t}$ is an antenna combination for N_m antennas. To select antennas, the Frobenius norm is considered. The Frobenius norm of $\bar{\mathbb{Q}}_q$ is as follows,

$$\Gamma\left(\bar{\mathbf{H}}_{q,t}\right) = Tr\left\{\bar{\mathbf{H}}_{q,t}\bar{\mathbf{H}}_{q,t}^H\right\}, \tag{11}$$

where Γ is calculated for each $\bar{\mathbf{H}}_{q,t}$ as shown in (3). In case 1, the selected antennas are as follows,

$$\bar{\mathbf{H}}_{q,t}^{opt} = \arg\max_{\bar{\mathbf{H}}_{q,t}} \Gamma\left(\bar{\mathbf{H}}_{q,t}\right), \tag{12}$$

where $\bar{\mathbf{H}}_{q,t}^{opt}$ is optimal channel matrix with the maximum Γ among the set of $\Gamma\left(\bar{\mathbf{H}}_{q,t}\right)$. In other words, the antennas are selected as an antenna combination of $\bar{\mathbf{H}}_{q,t}^{opt}$.

The number of the total combination for case 1 is as follows,

$$T_1 = \frac{N_t!}{(N_t - N_m)!N_t!}. \tag{13}$$

In case 2, Q is two and compound channels can be considered for antenna selection. When the compound channel is considered, the elements of $\bar{\mathbb{Q}}$ are compounded by permutation matrix, $\mathbf{P}_w$, as follows,

$$\bar{\mathbf{H}}_{c2} = \bar{\mathbf{H}}_{i,u} + \mathbf{P}_w\bar{\mathbf{H}}_{j,v} \quad \forall i \neq j, \tag{14}$$

where, $\mathbf{H}_i, \mathbf{H}_j \in \mathbb{Q}$, $\bar{\mathbf{H}}_{i,u} \in \bar{\mathbb{Q}}_i$, $\bar{\mathbf{H}}_{j,v} \in \bar{\mathbb{Q}}_j$. The i and j denote each index of two relays. The $\mathbf{P}_w$ changes the columns of $\bar{\mathbf{H}}_{j,v}$ for all possible permutations. The change of the columns means selection of an antenna to transmit data. The comparison of the compound channels provides additional diversity gain. The Frobenius norm for $\bar{\mathbf{H}}_{c2}$ is as follows,

$$\Gamma\left(\mathbf{P}_w, \bar{\mathbf{H}}_{i,u}, \bar{\mathbf{H}}_{j,v}\right) = Tr\left\{\left(\bar{\mathbf{H}}_{c2}\right)\left(\bar{\mathbf{H}}_{c2}\right)^H\right\}, \tag{15}$$

where Γ is changed by $\mathbf{P}_w, \bar{\mathbf{H}}_{i,u}, \bar{\mathbf{H}}_{j,v}$.

Furthermore, case 3 considers the compound channel between R_q. The compound channel of case 3 is as follows,

$$\bar{\mathbf{H}}_{c3} = \bar{\mathbf{H}}_{i,u} + \mathbf{P}_w\bar{\mathbf{H}}_{j,v} \;\; i, j \in R_q, \forall i \neq j, \tag{16}$$

where i and j denote each relay index of all R_q unlike fixed i and j in case 2. The Frobenius norm for $\bar{\mathbf{H}}_{c3}$ is as follows,

$$\Gamma\left(\mathbf{P}_w, \bar{\mathbf{H}}_{i,u}, \bar{\mathbf{H}}_{j,v}\right) = Tr\left\{\left(\bar{\mathbf{H}}_{c3}\right)\left(\bar{\mathbf{H}}_{c3}\right)^H\right\}. \tag{17}$$

Case 2 and 3 calculate each Γ based on (15) or (17). The selected antennas of case 2 and 3 are as follows,

$$\mathbf{P}_w^{opt}, \bar{\mathbf{H}}_{i,u}^{opt}, \bar{\mathbf{H}}_{j,v}^{opt} = \underset{\mathbf{P}_w, \bar{\mathbf{H}}_{i,u}, \bar{\mathbf{H}}_{j,v}}{\arg\max}\ \Gamma\left(\mathbf{P}_w, \bar{\mathbf{H}}_{i,u}, \bar{\mathbf{H}}_{j,v}\right), \tag{18}$$

where $\mathbf{P}_w^{opt}$ is optimal permutation matrix for $\bar{\mathbf{H}}_{i,u}^{opt}$ and $\bar{\mathbf{H}}_{j,v}^{opt}$. $\bar{\mathbf{H}}_{i,u}^{opt}$ and $\bar{\mathbf{H}}_{j,v}^{opt}$ are optimal antenna combination matrix of each R_q.

Both cases select $\bar{\mathbf{H}}_{i,u}^{opt}$ and $\bar{\mathbf{H}}_{j,v}^{opt}$ with maximum Γ. In cases 2 and 3, the compound channel is as follows,

$$\bar{\mathbf{H}}_c^{opt} = \bar{\mathbf{H}}_{i,u}^{opt} + \mathbf{P}_w^{opt}\bar{\mathbf{H}}_{j,v}^{opt}. \tag{19}$$

The total combination number of case 2 is as follows,

$$T_2 = T_1^2 N_m!. \tag{20}$$

Furthermore, the total number of the combination for case 3 is as follows,

$$T_3 = T_2 N_c. \tag{21}$$

The proposed scheme is to select the optimal relay considering the number of relays with an outage occurrence. Furthermore, the proposed scheme considers the compound channel for selection of relay and antenna. The proposed scheme achieves performance enhancement through the optimal compound channel and diversity from each case. Equations (13), (20) and (21) show the diversity order of each case. In the proposed scheme, the relay can be selected adaptively according to the system. The proposed scheme transmits same $\mathbf{x}$ to D_u. Multi-user detection scheme requires more channel feedback information than single-user detection scheme. The proposed scheme requires only a calculated Frobenius norm of channel quality indicator (CQI). However, the precoding scheme requires a CQI, a precoding matrix indicator (PMI) and rank indicator (RI). The system using the proposed scheme can be utilized in two cases. One is a broadcast case in which users require the same data and selections are not necessary. The other case is when all users receive the same data, but they requires different part of the data. In this case, each user disregards the other data. An algorithm of the proposed scheme is summarized in Algorithm 1.

Algorithm 1: Algorithm for proposed scheme

Data: CSI of $\mathbf{H_k}$ and $\mathbf{H}_q$, $B_{\mathbf{x}}$, N_p, N_m
Result: $R_q : q \in \{1 \ldots, Q\}$, $R_k : k \in \{1 \ldots, K\}$, $R_s : s \in \{1 \ldots, S\}$, $N_m : m \in \{1, \ldots, M\}$
initialize R_s **while** *Calculate outage probability* **do**
  find R_q
  if $Q < 2$ **then**
    case 1, $R_s = 1$
    for $s = 1$; **do**
      perform antenna selection
        generate antenna combination (10)
        calculate Γ (11)
        select N_m antennas with $\Gamma^{\max}$ (12)
  end
  else if $Q = 2$ **then**
    case 2, $R_s = R_q$
    for $s = 1$ *to* $S; s = q$ **do**
      perform antenna selection
        generate antenna combination with two compound channel (14)
        calculate Γ of compound channel (15)
        select N_m antennas with $\Gamma^{\max}$ (18)
  end
  else
    case 3, $Q > 2$
    for $q = 1$ *to* Q: $q \neq s$ **do**
      perform antenna selection
        generate antenna combination (16)
        calculate Γ of the compound channel (17)
        select N_m antennas and N_p relays (R_s) with $\Gamma^{\max}$ (18)
  end
end

5. Simulation Results

The simulation parameters are shown in Table 1. The number of symbols is 64 and the channel is a Rayleigh fading channel. The simulations iterate 100,000 times to sufficient for convergence of the Monte Carlo. To compare performance according to outage, modulation scheme uses both QPSK and 16-QAM. The detection scheme uses the zero-forcing (ZF) scheme to reduce the complexity of detection. Two distance ranges are used to compare the performance effect of distance. One of distance rate is divided into S to R_k and R_k to D_u based on 0.5. The other distance rate is divided into S to R_k and R_k to D_u based on 1. The distance rate 1 has a greater channel variation than the 0.5 distance rate. The maximum total distance of both two ranges is normalized to 1, and each relay has a random distribution within the range. The number of users is two and each user is detected by single user detection. The number of R_k and the antenna of the relay are simulated for four and eight to compare the performance according to the number of antennas and relays. For simplicity of simulation, N_l and N_m are fixed.

The proposed scheme is compared to the two schemes mentioned in Section 3. This is because above cited researches and proposed scheme are based on the capacity and Frobenius norm. For the equality of simulations, the capacity and Frobenius norm-based selection schemes use the same compound channel as the proposed scheme and select a relay with the largest capacity.

The simulation graphs show the user-average BER performances of proposed scheme, capacity and Frobenius norm-based selection schemes. Each number of N_t and N_r is four in from Figure 3. Figure 3a,b are shown using a 0.5 distance rate and Figure 3c,d are shown using a 1 distance rate. Figure 3a,c are shown using a 16-QAM modulation scheme and Figure 3b,d are shown using a QPSK modulation scheme. The simulation results show that the proposed scheme has improved BER performance than the capacity and Frobenius norm-based schemes. The capacity-based and Frobenius norm-based schemes have the same performance. In Figure 3a, the proposed scheme shows about 8 dB higher performance than the capacity and Frobenius norm-based schemes at BER of 10^{-2}. The overall graph shape of Figure 3b is similar to Figure 3a, but the performance of Figure 3b has higher performance than Figure 3a. The gain of BER performance increases especially at low SNR due to the frequent occurrence of outages. At BER of 10^{-2}, the proposed scheme in Figure 3b has about 6 dB higher performance than Figure 3a. The capacity and Frobenius norm-based schemes in Figure 3c has similar performance to Figure 3a. On the other hand, the BER performance of proposed scheme improves as the number of relays increase. The BER performance of the proposed scheme is improved by about 3∼7 dB based on BER of 10^{-2}. At the low SNR, proposed scheme has a nonlinear BER performance unlike Figure 3b due to the extended channel variation. Based on the six relays, the proposed scheme of Figure 3d has 6 dB performance gain compared to Figure 3c at BER of 10^{-3}. At BER of 10^{-4}, the proposed scheme of Figure 3d also improves the gain about $9 \sim 14$ dB than Figure 3b. The BER performances of the proposed scheme improve as the number of available relays increases. Figure 3c,d show that the diversity gain of relay gets greater as distance rate increases. Figure 4 show simulation results with N_t and N_r of eight. The composition of Figure 4 is the same Figure 3. The proposed scheme in Figure 4a has 7 dB higher performance than capacity and Frobenius norm-based schemes at BER of 10^{-2}. Furthermore, the proposed scheme in Figure 4a has 6 dB performance gain compared to Figure 4b at BER of 10^{-2}. Since N_m is fixed, BER performances of Figure 4a,b are greater by 1 dB than the performances of Figure 3a,b with the same number of N_t and N_r,. On the other hand, Figure 4c,d show higher performance gains than Figure 3c,d due to the large channel variation. In Figure 4c, the proposed scheme has more performance gain by 3 dB at BER of 10^{-3} than the gain of Figure 3c. Figure 4d shows improvement for the degradation caused by the outage occurrence at the lower SNR as shown in Figure 3d.

Table 1. Simulation parameters.

<table>
<tr><td>Number of symbols</td><td colspan="2">64</td></tr>
<tr><td>Modulation</td><td colspan="2">QPSK, 16-QAM</td></tr>
<tr><td>Channel</td><td colspan="2">Rayleigh fading</td></tr>
<tr><td>MIMO detection</td><td colspan="2">Zero forcing</td></tr>
<tr><td rowspan="4">Distance rate</td><td colspan="2">Random distribution</td></tr>
<tr><td>Source to Relay</td><td>Relay to Destination</td></tr>
<tr><td>0 to 1</td><td>0 to 1</td></tr>
<tr><td>0 to 0.5</td><td>0.5 to 1</td></tr>
<tr><td>Transmit power</td><td colspan="2">Normalization to 1</td></tr>
<tr><td>Number of users</td><td colspan="2">2</td></tr>
<tr><td>Number of relays</td><td colspan="2">4, 6, 8</td></tr>
<tr><td>N_t and N_r</td><td colspan="2">4, 8</td></tr>
<tr><td>N_l</td><td colspan="2">2</td></tr>
<tr><td>N_m</td><td colspan="2">2</td></tr>
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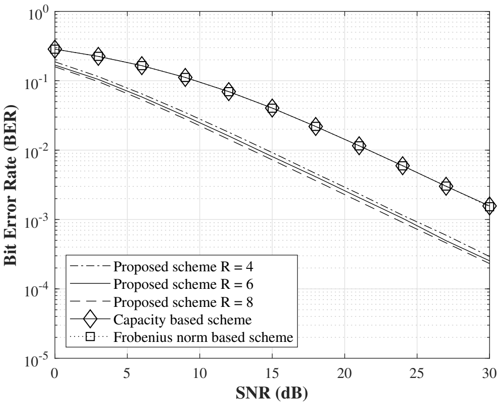
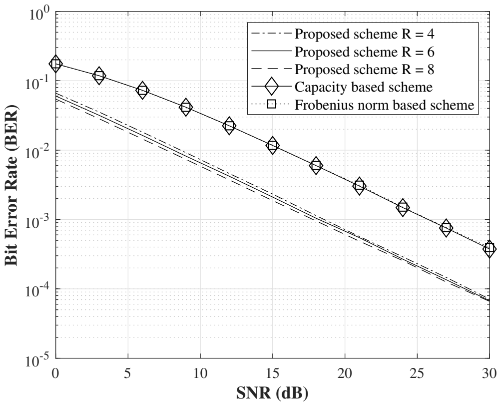
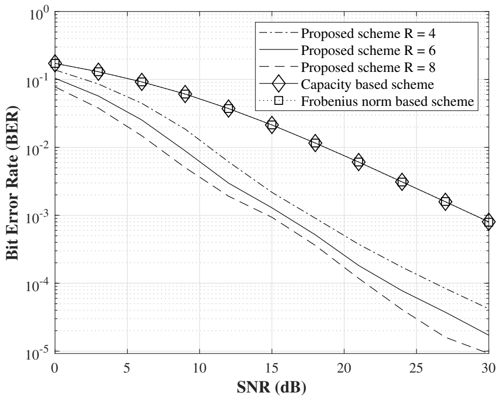


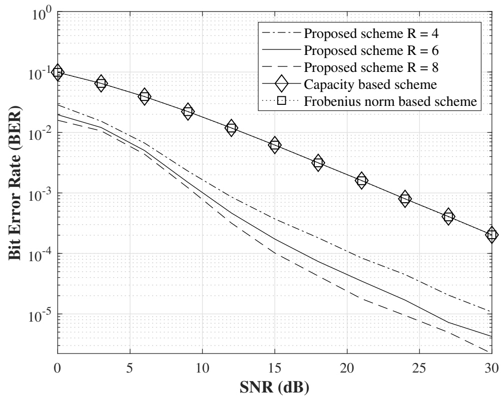
(**a**) 0.5 distance rate and 16-QAM modulation scheme



(**b**) 0.5 distance rate and QPSK modulation scheme



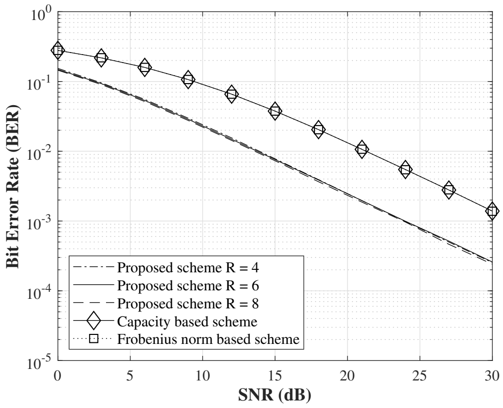
(**c**) 1 distance rate and 16-QAM modulation scheme



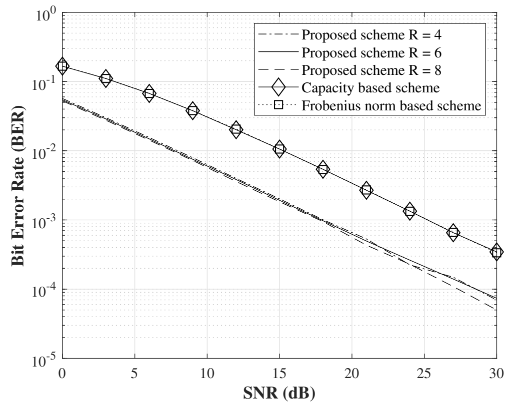
(**d**) 1 distance rate and QPSK modulation scheme

Figure 3. BER performance with 4 antennas

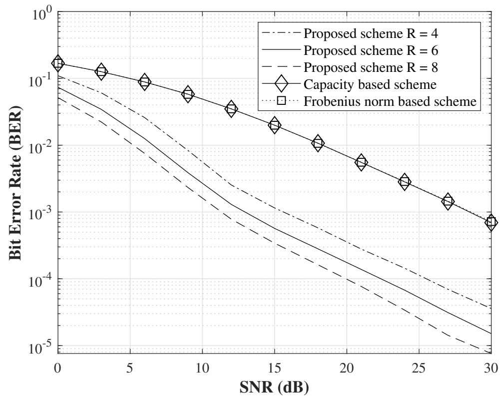
The simulation results show that the proposed scheme has an improvement of performance through the diversity gain than other schemes. Even for low SNR, the proposed scheme achieves high performance through an antenna selection with optimal compound channel. Furthermore, diversity gain with a compound channel clearly increases with Q and SNR. When relay is widely distributed, the BER performance of proposed scheme can be improved. According to distance rate, the conventional schemes have 3 dB performance gain but proposed scheme has about 8$\sim$13 dB gain. Through fixing the number of selected antennas, the simulation results show that the proposed scheme is more affected by relay diversity gains than antenna diversity gains. The performance gains can be increased with more relays and antennas.



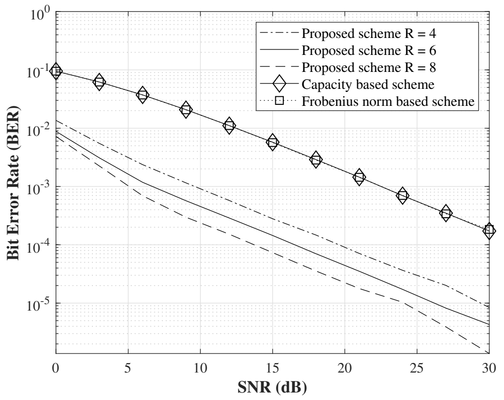
(**a**) 0.5 distance rate and 16-QAM modulation scheme



(**b**) 0.5 distance rate and QPSK modulation scheme



(**c**) 1 distance rate and 16-QAM modulation scheme



(**d**) 1 distance rate and QPSK modulation scheme

Figure 4. BER performance with 8 antennas

6. Conclusions

As one of the relay selection techniques, the proposed scheme uses a new algorithm for enhancing the performance of single link. A new algorithm consists of two stages. The first selection stage guarantees the reliability by considering the outage occurrence. The three cases are defined according to Q in the first selection stage. In the second selection stage, antenna selection is performed based on the compound channel for each case. Through two stages, the proposed scheme obtains diversity gain from various combinations of relays and antennas. The proposed scheme achieves improved BER performance than other schemes. As the channel variation of relays increases, the proposed scheme shows the improved BER performance. Furthermore, the diversity gain of proposed scheme increases with the number of available relays and antennas.

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